Radiation Dosimetry

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Self Reliance in Personnel Monitoring of Radiation Workers in India

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TLD badge

ABSTRACT

The Personnel Monitoring Service (PMS) equipped with in-house developed $CaSO_4$: Dy based TLD badge has been provided to all radiation workers by BARC. Currently, more than 220,000 radiation workers are covered by the TLD Badge System for monitoring Gamma, X-ray and beta radiations. Neutron monitoring based on CR-39 detector is also provided to 3800 radiation workers. Complete self reliance has been achieved in the field of TLD based personnel monitoring.

KEYWORDS: *Personnel monitoring, $CaSO_4$:Dy Teflon disc, TLD badge, Neutron badge*

Introduction

The Department of Atomic Energy (DAE) since its inception, has accorded high priority to safety in radiation activities (Atomic Energy Act, 1962 and Radiation Protection Rules 1977 and 2004). The measurement of occupational radiation doses of radiation workers started since the inception of the Department of Atomic Energy (DAE) as evident from the monitoring records of occupational doses available in the national dose registry since 1953 onwards [1]. Personnel Monitoring Service (PMS) has been provided to all radiation workers by Bhabha Atomic Research Centre (BARC) through the erstwhile Directorate of Radiation Protection (DRP) and Radiological Physics and Advisory Division (RPAD). Apart from the DAE, the monitoring service is extended to all the other Non-DAE institutions in the country and a few medical institutions from Nepal and Bhutan.

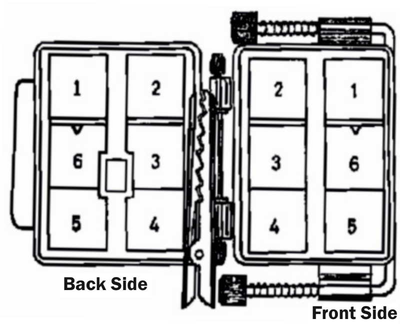
Film Badge System

Regular PMS based on photographic film dosimetry was started in 1957 for departmental radiation workers by the Radiological Monitoring Laboratory which was housed at the Tata Institute of Fundamental Research (TIFR), later known as Radiological Measurements Section [2]. The Film Badge consisted of two components: a film pack with double-layer emulsion coating on the plastic base and a metal holder to contain that film. The film pack had a 3cm x 4cm transparent polyester film with a cellulose acetate base of ~200 μm thick having more sensitive (fast) emulsion coating (grain size ≅2 μm) on one side and less sensitive (slow) emulsion coating (grain size ≅1 μm) the other side. This film, sandwiched between two black papers is enclosed in a lightproof plastic and has a flap to open in the darkroom for processing.

The film-pack was loaded into a metallic cassette having 5 metallic filters, namely plastic, cadmium, thin-copper, thick-copper, and lead (Fig.1). The thickness of all the filters is 1 mm except for the thin-copper filter (0.15 mm). These filters were incorporated to facilitate the identification of incident radiation, determination of energy and dose evaluation from multiple radiation exposures of X-rays, beta, and gamma. The cadmium filter facilitated the dosimeter to record thermal neutron dose by $^{113}Cd(n, \gamma)^{114}Cd$ reaction as well. The radiation level was indicated by the optical density results under different filter regions due to the darkening of the film.

TLD Badge System

The TLD badge based on CaSO4:Dy Teflon was indigenously developed in 1975 at BARC [3,4]. It is currently used for countrywide Personnel Monitoring of more than 2,20,000 radiation workers in India through 17 monitoring laboratories. The TL phosphor has an optimum Dy concentration of 500 ppm (0.05 mol %) and exhibits a main TL glow peak at about 220°C and two small satellite peaks on higher and lower temperature sides. The TL response is linear in the dose range of interest in radiation protection (0.1 mSv-1Sv). The $CaSO_4$:Dy phosphor is embedded in Polytetrafluoroethylene (PTFE) (Teflon- 7A grade) in a weight ratio of 1:3. The TLD Badge comprises a TLD Card having three TLD Discs (13.3 mm dia and 0.8 mm thick), which are mechanically clipped on an aluminium plate (52.5 mm x 30.0 mm x 1.0 mm). The card is wrapped in thin paper (thickness ~10 mg/cm^2) containing printed information regarding the user and service period, and further sealed in plastic pouch (thickness ~ 3 - 4 mg/cm^2) before being loaded in the cassette (Fig.2).



1. Open Window
2. Plastic
3. Cadmium
4. Thin Copper
5. Thick Copper
6. Lead

Fig.1: Film badge (chest holder).

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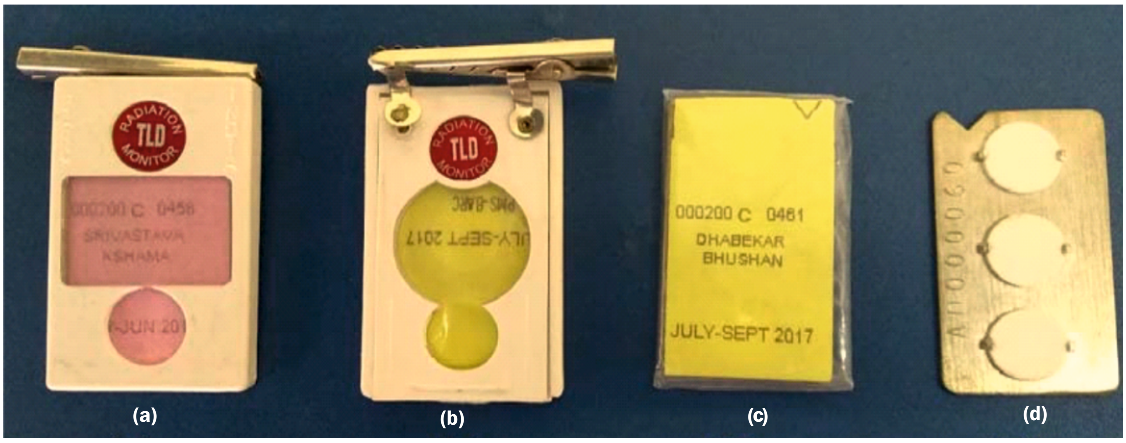

Fig.2: TLD Badge: (a) Front View, (b) Rear View, (c) TLD Card Loaded in Wrapper and Polythene Pouch, and (d) Bare TLD Card.

The plastic cassette has three filter regions: (i) metal filter combination of 1.0 mm Cu and 0.6 mm Al filter, (ii) 1.6 mm thick plastic filters, and (iii) open window. There are three types of TLD Badges in use: Chest Badge, Wrist Badge, and Head Badge for monitoring whole body dose, extremity dose and eye lens dose, respectively. TLD Badge is used for evaluating the dose received by radiation workers due to x-rays, gamma, and beta fields using a suitable dose evaluation algorithm [4]. TLD Badge exhibits an energy-dependent response for photons and beta radiation which is compensated by using multiple filters and the dose evaluation algorithm.

TLD Badge Reader Systems

The appropriate readout systems for the processing of the TLD Badges were also developed at BARC. Earlier, the manual TLD Badge Reader System (model TLDBR-3B) based on contact heating was used till 1999. Presently a PC-controlled semiautomatic TLD Badge Reader (model TLDBR-7B or equivalent) is being used for the readout of the TLD Card for Personnel Monitoring [5]. The Reader has provision for heating of TL discs by hot N_2 gas and automatic reading of 50 TLD Cards in ~100 minutes. This reader utilizes a reproducible, non-linear clamped heating profile for heating the dosimeter to get integral TL-signal measurement. The reader consists of microprocessor-based electronic control circuits, PMT housing, card transport system, N_2 gas heater and temperature control unit, cooling fans and solenoid to control the gas flow (Fig.3).

Neutron Personnel Monitoring Service

The CR-39 based neutron badges are being used for countrywide Fast Neutrons Monitoring (FNM) of 3800 workers from the field of nuclear reactors, accelerators, fuel processing plants, well-logging etc[7]. CR-39 (poly allyl diglycol carbonate-PADC) is a Solid State Nuclear Track Detector (SSNTD) and detects the fast neutrons (above 100 keV) by recoil proton mechanism. The FNM service is provided by a single centralized Laboratory of Radiological Physics & Advisory Division (RPAD), BARC on a quarterly basis. The neutron badge comprises a CR-39 detector (3 cm x 3cm x 0.075 cm) with a 1 mm thick polyethylene radiator in the front, sealed together in an air-tight triple laminated aluminized pouch which is further loaded in a plastic holder. Fig.4 shows all the components of the neutron badge along with the assembled Chest and Wrist Neutron Badge.

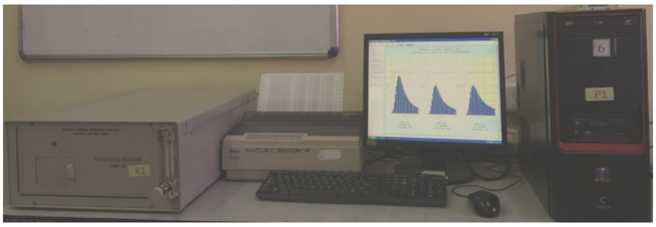

Fig.3: TLD Badge Reader (BR-7B).

The CR-39 badges are processed by an Electro Chemical Etching (ECE) using a specially designed ECE cell wherein the electrode is dipped into the 7 N KOH solution in the cavity through which current is allowed to pass by applying high voltage [5]. The processed detectors are counted for tracks using an automated image analysis system developed by SESSD(erstwhile EISD), BARC.

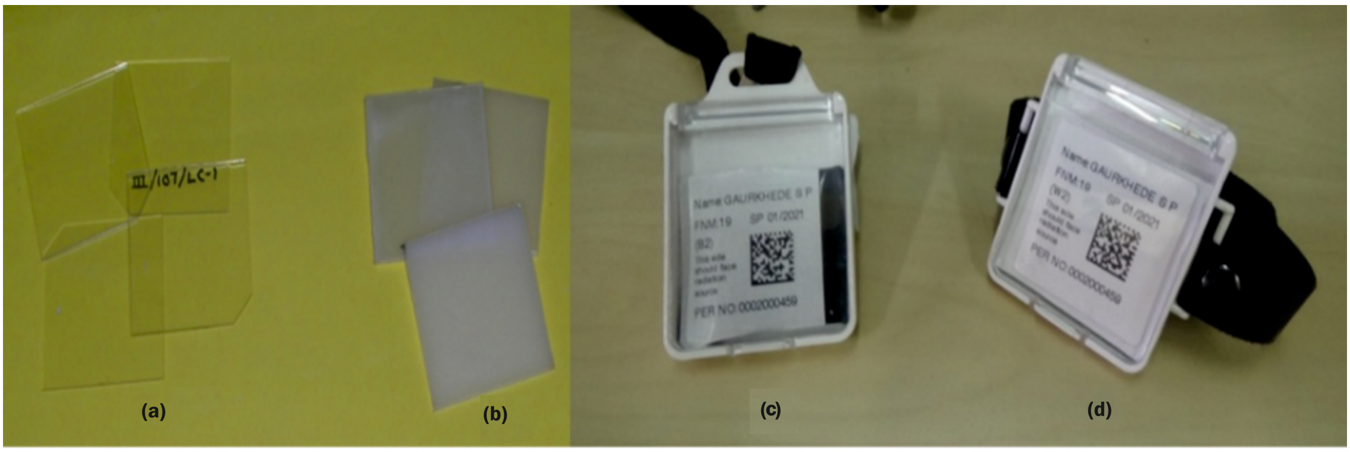

Fig.4: Neutron Badge components (a) CR-3 foils (b) Polyethylene radiator (c) Chest badge and (d)Wrist badge.

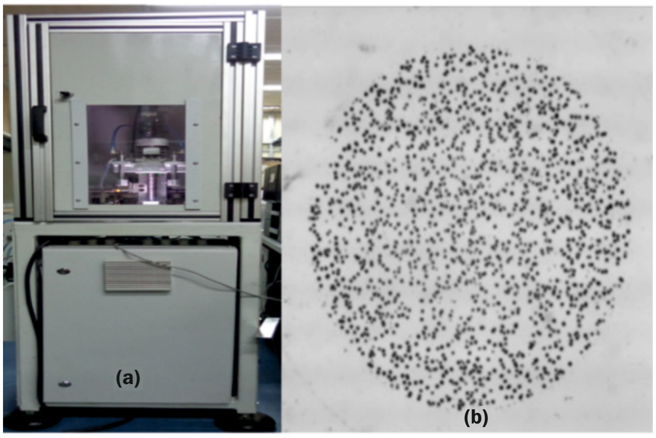

Fig.5: (a) Automated imaging system (b) Tracks in CR-39.

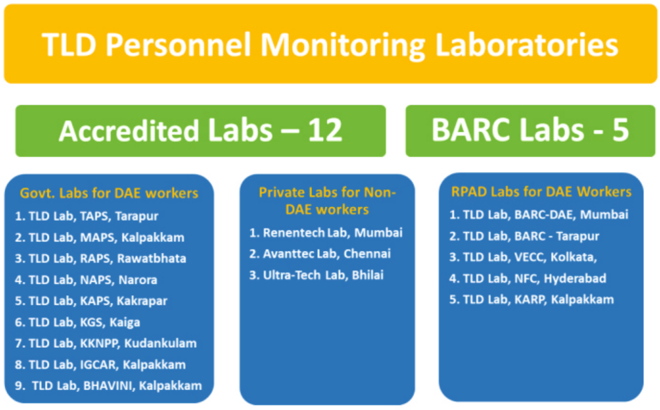

Fig.6: 17 TLD Personnel Monitoring Laboratories in the country.

The automated imaging system with 'vacuum pick-up and place' feature has the capacity to process 100 CR-39 detectors at a time (Fig.5). Image capturing is done with 5MP camera and the software is capable of saving and importing track counting data against each bar-coded badge of radiation workers. The entire data is saved in an Excel sheet to communicate between the imaging system and 'ANUKOSH', a Neutron Dose Database Management Software which is also developed indigenously for dose report generation.

For higher neutron doses, Chemical Etching (CE) process is carried out at 7h in 7N KOH at 60°C and is calibrated for dose linearity up to 100mSv.

Technology Transfer of TLD Badge System

Technology transfer to several private companies to meet the industry requirements has made the TLD badge system commercially available and has helped in enhancing the infrastructure for further scaling of service as per demand. The standardization of production procedures of TLD badges, readers and dosimetric procedures, protocols has further paved the way for the decentralization of personnel monitoring services and economically viable for the private sector.

Expansion of Monitoring Service through Accredited Laboratories

To cater to this increased demand for personnel monitoring, BARC started an accreditation program in 1999 to share the workload with private sector for the multi-fold expansion of this service. The methodologies were developed, and required documentation was made available for the accreditation of TLD laboratories. At present, out of total 17 laboratories in the country, 12 laboratories are accredited by BARC, including 3 from the private sector, 7 from NPCIL and one each at IGCAR and BHAVINI (Fig.6). The remaining five TLD monitoring laboratories of RPAD, BARC provide service, mainly to radiation workers of BARC and other DAE facilities. The entire Non-DAE workload of approx. 2,00,000 radiation workers from medicine, industry, agriculture and research applications are covered by the three private TLD laboratories. These accredited laboratories are provided with technical and scientific support by BARC. The expansion of services through Accredited Laboratories has helped to meet the service demand and disseminate the technical know- how developed at this centre over the years.

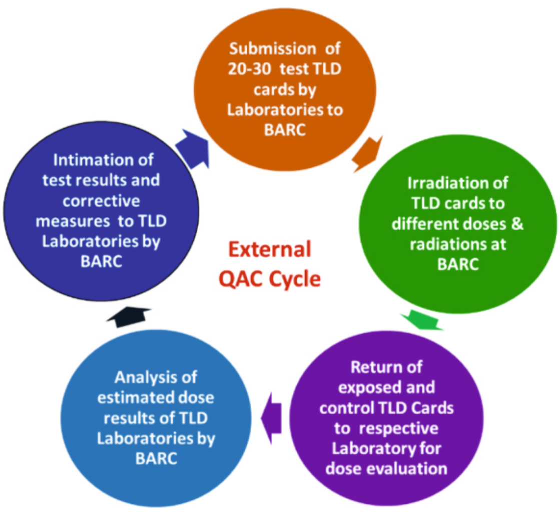

Fig.7: External Quality Assurance Check (QAC) conducted for TLD Laboratories in the country.

Quality Assurance in TLD Personnel Monitoring

Quality Assurance (QA) plays an important role in such a widespread monitoring program to ensure the accuracy and reliability of service as per the international performance standards. QA program includes internal QA check by the processing laboratory and adequate check on their performance by an external/neutral entity. In India, a program of External Quality Assurance Check (QAC), was devised for periodic performance evaluation of various monitoring laboratories through a postal exercise [2,8]. This external QAC was initiated in 1985 and total 47 QAC cycles have been completed so far. Under this program, the performance of each TLD laboratory is assessed in radiation categories of the photon, beta and mixed photon-beta field as per the acceptance criterion of the American National Standards Institute (ANSI) and Trumpet Curve method ISO 14146.

In neutron personnel monitoring, internal QA is maintained by the processing laboratory by calibrating and standardizing all the procedures and equipment. The neutron dosimetry group, RP&AD has participated in EURADOS intercomparison exercise-2017. Response of BARC neutron badge was within the acceptable limits(0.5–2.0) as per ISO-14146 [9].

Conclusion

In routine personnel monitoring, thousands of cards are processed monthly and it needs to be ensured that the dosimetric accuracy is not compromised. The dosimetric accuracy mostly relies on the accuracy of the signal i.e. GC. With the continuous increase in the number of monitored occupational workers, there is a need for automation to increase the throughput of TLD personnel monitoring laboratories without compromising dosimetric accuracy. Therefore, the application of ML algorithms into the GC-screening process which is one of the mandatory steps in TLD processing will surely improve the throughput of the laboratory. Also, with human intervention, the variability in decisions about the correctness of GC results in subjectivity. The subjectivity can also be minimized with the use of AI-based algorithms. Further, the use of a probabilistic approach gives an insight into the anomaly as well as provides a health diagnosis of the TLD reader which serves as predictive maintenance system.

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